Subpicosecond Fiber Optical Parametric Chirped Pulse Amplifier Based On Highly-Nonlinear Fiber

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Abstract: We experimentally demonstrate a fiber optical parametric chirped pulse amplifier. A 750-fs signal is stretched to 40 ps, amplified with a gain of 30 dB through parametric process and then compressed to 808 fs.

OCIS codes: (060.4370) Nonlinear optics, fibers; (190.4970) Parametric oscillators and amplifiers.

1. Introduction

Optical parametric chirped pulse amplification (OPCPA) has been investigated comprehensively [1] and is recognized as a key technique to amplify ultrafast pulses. Using OPCPA configuration, people can achieve extremely high peak power pulses [2]. OPCPA has some advantages over other CPA techniques, such as a broad bandwidth, good thermal properties, and access to arbitrary wavelength ranges [1]. OPCPA in optical fibers, which is called fiber optical parametric chirped pulse amplification (FOPCPA), has been proposed and numerical simulated by Hanna *et al.* [3]. Comparing with conventional OPCPA systems based on $\chi^{(2)}$ nonlinear effect of crystals, FOPCPA based on $\chi^{(3)}$ nonlinear effect of optical fibers allows a longer interaction length, eliminates the need for alignment and offers further integration with other fiber components.

In this paper, a FOPCPA is experimentally demonstrated. We use a 750-fs pulse at 1595 nm as the input signal of the FOPCPA system. The peak power of the signal is amplified from 93 mW to 10 W. The proof-of-concept demonstration of FOPCPA may lead to further development of the OPCPA system. The fiber-integrated nature of the whole system allows complete self-alignment and further integration to other fiber-based systems.

2. Experimental Setup

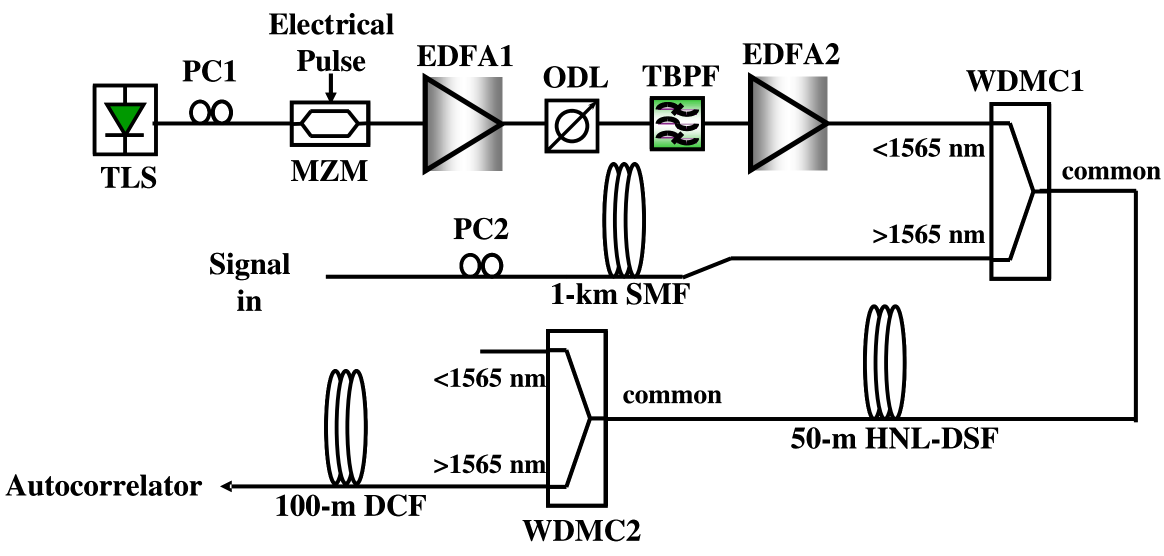

Fig. 1. Experimental setup of the FOPCPA. EDFA: erbium-doped fiber amplifier, TBPF: tunable band-pass filter, MZM: Mach-Zehnder modulator, HNL-DSF: highly-nonlinear dispersion-shifted fiber, WDMC: wavelength-division multiplexing coupler, ODL: optical delay line.

The experimental setup of the FOPCPA is shown in Fig. 1. The signal we chose had a center wavelength of 1595 nm, pulsewidth of 750 fs and linewidth of 5 nm. Polarization controller PC2 was used to align the state of polarization (SOP) of the signal with that of the pump so as to maximize the parametric gain. A spool of 1-km single-mode fiber (SMF) with a dispersion of 20 ps/nm/km at 1595 nm was used to stretch the signal from 750 fs to 40 ps, with a stretching ratio of larger than 50. The peak power of the signal decreased from 93 mW to 1.5 mW after the stretcher. The pump source was a tunable laser source (TLS), which was fixed at 1555 nm. The continuous-wave (CW) output of

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the TLS was intensity-modulated by a 100-MHz electrical pulse with duty ratio of 1/100 to produce optical pump pulse with pulsewidth of 100 ps and repetition rate of 100 MHz. It was then amplified by EDFA1 and EDFA2 and filtered by the TBPF with a linewidth of 1-nm to produce low-noise, high power pump. The ODL was used to synchronize the pump with the signal. The pump and signal were combined by WDMC1 with a separation wavelength at 1565 nm and launched into a 50-m HNL-DSF which had nonlinear coefficient of 14 $W^{l}km^{-1}$, zero-dispersion wavelength of 1554.7 nm and dispersion slope of 0.035 ps/nm^2/km for parametric process. After parametric amplification, the signal was filtered by WDMC2, and compressed by a spool of 100-m dispersion compensation fiber (DCF) with a dispersion of -96.6 ps/nm/km at 1595 nm to achieve a high peak power. The pulsewidth of the compressed signal was measured using an autocorrelator.

3. Results and Discussions

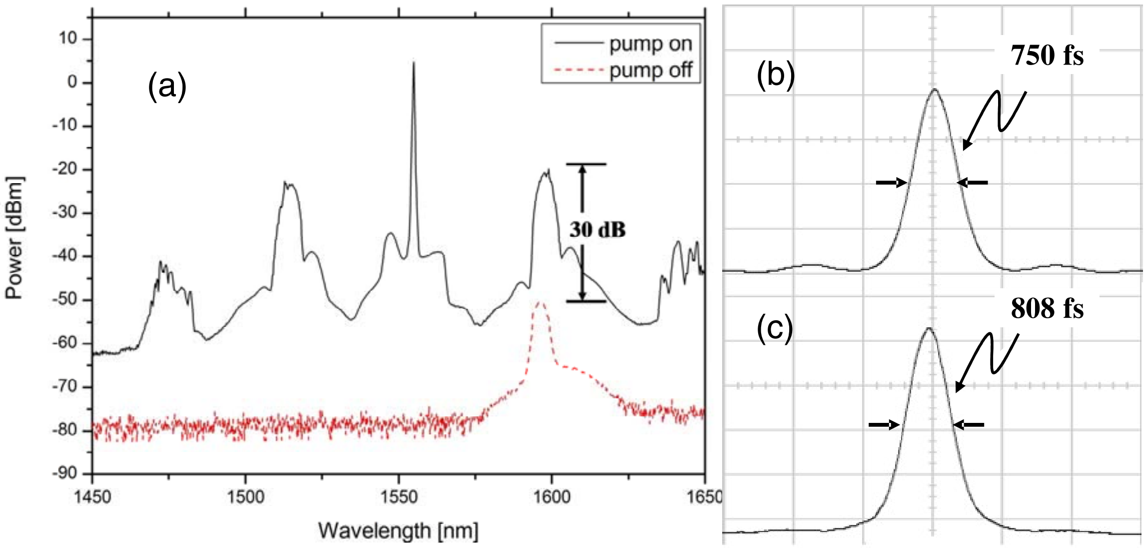

Fig. 2. (a) Optical spectra measured at HNL-DSF output when the pump is switched off (red dashed line) and on (black solid line); (b) autocorrelation trace of the original signal pulse and (c) autocorrelation trace of the amplified signal after compression.

Fig. 2 (a) shows the signal spectra measured at the HNL-DSF output when the pump is switched off (red dashed line) and on (black solid line). It can be observed that the signal receives a parametric gain of 30 dB, and a strong idler at 1514 nm is also generated. The smaller peaks are due to the spurious four-wave mixing (FWM). The pedestal at the bottom of the pump is due to the amplified spontaneous emission (ASE) noise from the EDFA2. The peak power of the signal pulse after HNL-DSF is measured to be 1 W.

Fig. 2 shows the autocorrelation traces of the original signal pulse (b) and the amplified signal pulse after compression (c). The amplified signal, which has a pulsewidth of 40 ps and peak power of 1 W, is compressed by the DCF. The compressed pulse has a peak power of 10 W, and a pulsewidth of 808 fs, slightly wider than the original corresponding signal pulse. The wider pulsewidth is possibly due to residual high-order dispersion of the compressor.

4. Conclusion

In conclusion, we demonstrated a FOPCPA to amplify a subpicosecond signal at 1595 nm. The 750-fs signal was stretched to 40 ps, amplified by an all-fiber optical parametric amplifier and then compressed to 808 fs. The peak power of the signal was amplified from 93 mW to 10 W. This technique has potential applications in amplification of ultrafast pulses in non-conventional wavelength bands.

5. Acknowledgment

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